Compensating attenuation due to shallow gas through Q tomography and Q-PSDM, a case study in Brazil
Joe Zhou*, Sergey Birdus, Barry Hung, Keat Huat Teng, Yi Xie, CGGVeritas Singapore
Dimitri Chagalov, Amy Cheang, Darrell Wellen (Chevron Energy Technology Company, Perth, Australia) and John Garrity (Chevron Brasil Petróleo Ltda, Rio de Janeiro Brasil)

Summary
The presence of gas, both as shallow pockets and as commercial reservoirs, has long been recognized as a significant problem in imaging seismic data. In this paper we describe how we successfully applied Q tomography and Q-PSDM technology to compensate the phase, frequency and amplitude loss due to shallow absorption, thus improving structure imaging and potentially accurate AVO/DHI analysis underneath shallow gas.

Introduction
The shallow gas anomaly has long been recognized as a significant problem in seismic data processing. It has been seen to be so serious an issue in places like the North Sea that efforts to see through the gas have involved expensive acquisition solutions such as ocean bottom shear wave recording. This problem is also becoming increasingly recognized as an issue in other regions such as Offshore Brazil as more and more exploration and development attention was drawn there. Conventionally processed data cannot be used for inversion when these problems remain uncorrected; mapping of the structures within the oil and gas field become problematic; auditing of reserves is less reliable.

CGGVeritas has recently developed a new technology based on the Quality (Q) Factor to address this challenge. In this article, we describe how we successfully applied the Q Tomography and Migration on data from Frade field, offshore Brazil.

Attenuation due to shallow gas
The propagation of seismic waves through viscoacoustic media is affected by the attenuation, characterized by the quality factor Q, resulting in significant loss of signal strength and bandwidth. Gas trapped in sediment is an extreme example of these media. Figure 1 shows a depth migrated seismic section showing attenuation due to overlying shallow gas. Seismic images of geological structures underneath shallow gas often suffer from resolution degradation and the effect of amplitude dimming, making their identification and interpretation difficult. This in turn affects the ability to accurately predict/interpret the deeper reservoir properties and structures. Thus, there is a need to compensate for the attenuation.
Compensating attenuation due to shallow gas through Q tomography and Q-PSDM

Q Tomography and Anisotropic Depth Migration

Complete Q compensation involves the estimation of Q and then using the resultant Q volume to correct the amplitude and phase effects. CGGVeritas has recently developed a ray based tomographic method for estimating Q that takes into account the actual dips of the 3D structure because the analysis is performed on the depth migrated data. Its implementation steps can be summarized by Figure 2 in which an offset volume of certain frequency is shown. Assuming a horizon has been picked, an amplitude ratio map can be generated along the horizon using reference average amplitude that is taken from locations that are not affected by the attenuation anomalies. Through ray-tracing, the attenuation effect can be accumulated along the ray-paths. By repeating the process for other frequencies and offsets, a Q volume can be estimated through tomographic inversion (Xin and Hung, 2009).

The resulting Q volume can then be used for mitigating the attenuation effects on amplitude, frequency and phase of the affected seismic signal through migration. This can be done in our Q prestack depth migration (Q-PSDM) in which the velocity of the attenuation medium is treated as a complex number that is a function of Q. With this complex velocity, an anti-dissipation term can be included in the migration operator for restoring the seismic response (Xie et al., 2009). Thus, the procedures involve the computation of the conventional traveltime and the complex dissipation time that accumulates the Q effect along the raypath. Since anisotropy as a result of rock properties is easily to be incorporated in the conventional travelt ime calculation, our method is capable of performing anisotropic Q-PSDM not only to compensate the attenuation effects, but also to image the subsurface structures at the correct locations.

Field data results

Frade field is located in the Campos Basin about 120km offshore the state of Rio de Janeiro. The main processing objective is to obtain a high resolution seismic image and thus provide clear understanding of the internal channel architecture through MAZ processing. The compensation of the anomalous absorption due to shallow gas clouds is one of the key parts of the integrated solution. After preprocessing and several iterations of anisotropic velocity update, one of the three azimuth datasets was first migrated with a conventional TTI PSDM without Q as shown in Figure 1. Amplitude dimming caused by gas in shallow region was observed especially for the three reservoir layers right beneath (N570 Miocene, N560 Lower Miocene and N545 Oligocene). The amplitudes along the key horizons provided by Chevron were measured and this information was used in the tomographic inversion for estimating the Q due to the shallow gas. Figure 2 shows the amplitude ratio map along N570 horizon, there is apparent amplitude cut along the edge of the gas shadow in the map. The initial Q model was estimated through tomographic inversion and Q-PSDM was then run to boost up the amplitudes of the events within the dim zone so that the events could be picked for velocity analysis. Both the Q model and the velocity model were updated iteratively a couple of times before optimum models were obtained. Multi-azimuth tomography for both the Q update and velocity update were used to incorporate the information from all three azimuths which help to provide a superior Q and velocity model with higher resolution. Figure 3 displays the final Q profile and figure 4 displays the final velocity model. The final Q model and TTI velocity model were then used in the final QPSDM. In the initial test, it was noticed that the residual high frequency noise was also greatly boosted by the Q migration operator even though the residual noise is hardly visible in the migration input. An iterative de-noise approach was then used by modelling the noise with Q compensation but subtracting the noise model after backing off the Q compensation from the migration input.

![Figure 3. The Q model from Q Tomography.](image1)

![Figure 4. Final velocity model (V0).](image2)
Compensating attenuation due to shallow gas through Q tomography and Q-PSDM

Figure 5, 6 and 7 compare the conventional PSDM and QPSDM results. It can be observed that the amplitudes of the events underneath the shallow gas are restored, wavelets are sharper, the continuity is improved and the sag in the structure is reduced. More importantly the CIG gathers now are more reliable for the AVO/DHI analysis. All of these enable the correct interpretation of the stratigraphy within the hydrocarbon zone.

Conclusions

The importance of Q compensation through Q Tomography and Q-PSDM in the presence of viscoacoustic media such as shallow gas has been demonstrated through this project. For areas where shallow gas is a common phenomenon, this newly developed technology presents a solution to the challenge of revealing and imaging hydrocarbon reservoirs below attenuative medium.

Acknowledgements

We would like to thank Frade Concession Partners - Chevron Brasil Petróleo Limitada, Petrobras, Frade Japão Petróleo Limitada and CGGVerisias for permissions to publish this paper. We would also like to thank James Sun for his valuable input for this paper.

Figure 5. Seismic stack section. (a) Stack after conventional PSDM. (b) Stack after Q tomography and Q-PSDM. (c) Wiggle display of conventional PSDM stack (filled with black colour) overlaid on Q-PSDM stack. (d) Amplitude spectrum plots of (a) and (b) around the gas pocket and reservoirs.
Compensating attenuation due to shallow gas through Q tomography and Q-PSDM

Figure 6. Seismic CIG section. (a) CIG gathers after conventional PSDM. (b) CIG gathers after Q tomography and Q-PSDM.

Figure 7. Seismic depth slices: left one is after conventional PSDM; right one is after Q tomography and Q-PSDM. It can be observed that the amplitude truncation of the events underneath the shallow gas is restored.
EDITED REFERENCES
Note: This reference list is a copy-edited version of the reference list submitted by the author. Reference lists for the 2011 SEG Technical Program Expanded Abstracts have been copy edited so that references provided with the online metadata for each paper will achieve a high degree of linking to cited sources that appear on the Web.

REFERENCES